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THE WESTERN CABBAGE FLEA-BEETLE.[1]

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Truck-Crop Insect Investigations.

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NATURE OF INJURY.

An insect enemy of cabbage, turnip, and other cruciferous crops, known as the western cabbage flea-beetle, ranks as a most troublesome pest in the region which it inhabits.[2]

It is primarily an enemy of gardens, but quite too frequently becomes a pest in large commercial plantings. The chief injury is done by the overwintered beetles attacking turnip, radish, and other cruciferous vegetables just as they are coming through the ground, and by the beetles of the first generation, which are usually at the maximum of their destructiveness during June and July. The beetles appear suddenly, and frequently in incalculable numbers, and large areas are completely devastated before the grower becomes aware of their presence.

Although the larvæ feed on the roots of cruciferous vegetables, they cause little appreciable damage.

The beetles are by no means confined in their injurious attacks to cabbage and other cole crops, since when they occur in unusual abundance they attack most forms of vegetable crops, including beans, peas, table and sugar beets, mustard, kale, and rape. As with

[1] *Phyllotreta pusilla* Horn; family Chrysomelidae, order Coleoptera.

[2] This insect was under observation by the junior author (deceased) from 1909 until 1917, at Rocky Ford, Colo.

the majority of flea-beetles, this species does most harm to young plants, and, as an instance of its destructiveness, it has been reported to come in swarms, like black clouds, completely covering the plants.

This species is not a periodical pest, like army worms and others, but it is more or less injurious year after year in the regions which it inhabits. It is, however, like most other flea-beetles, subject to considerable fluctuation in numbers for reasons which have not yet been entirely explained, but which are doubtless due to atmospheric conditions either at the time that the insect is breeding or when it is in hibernation.

DESCRIPTION.

BEETLE.

The adult of the western cabbage flea-beetle (fig. 1) is shining metallic copper in color, measuring one-sixteenth of an inch or a little more in length. The body is elongate oval, much flattened. The antennæ are slender and the same in both sexes. The thighs of the hind legs are strongly developed, fitting the insect for jumping, whence its common name of "flea" or flea-beetle.

FIG. 1.—The western cabbage flea-beatle (*Phyllotreta pusilla*): Adult, highly magnified.

Following is the original description of *Phyllotreta pusilla* (*3*,[1] *p. 302*):

Form narrow, elongate, depressed, piceous, surface with distinct æneous lustre. Antennæ slender, half as long as the body, piceous, joints 2–3 paler. Head scarcely visibly punctate. Thorax less than twice as wide as long, widest at middle, sides arcuate, apex slightly narrower than base, disc convex, surface shining, the punctures moderate, closely placed, but not convex. Elytra wider than the thorax, humeri obtuse, punctation coarser than that of the thorax, closely placed, very little finer near the apex, but less dense, surface shining. Body beneath and legs piceous, abdomen sparsely punctate. Length .06—.08 inch; 1.5–2 mm.

Male.—Last ventral [segment] with a feeble triangular impression in the apex.

Female.—Last ventral simple.

The antennæ are alike in both sexes and the joints 3 to 10 vary little in length, although slightly broader externally.

This species is very easily confounded with related forms of similar habits. Prominent among these is *Phyllotreta albionica* Lec., which it resembles so nearly in form, size, and color that the females can scarcely be separated. It is, however, more shining, the head is nearly smooth, and the thorax and elytra are less densely punctate. Moreover, *Ph. albionica* may easily be separated by the male antennæ which have the fifth joint dilated. The female antennæ of the two species are almost identical. The color of *pusilla* is sometimes olive brown and inclined to black, but examination of a large series of properly preserved specimens does not show any material variation,

[1] Reference is made by number (italic) to "Literature cited," p. 21.

except in a few darker individuals from northern Colorado, the normal color being almost uniformly cupreous or copper-colored. The species is also apt to be confused with *Ph. aeneicollis* Cr., but the latter may be readily distinguished, inasmuch as it is more convex, more shining, and distinctly larger.

EGG.

The egg is light yellow, glistening, of oval form, and about 1/50 of an inch in length.

In confinement eggs were deposited in cracks in the soil about the roots of the cruciferous plants on which the larva subsists and there is good reason to believe that this is the usual habit under field conditions.

LARVA.

The larva (fig. 2, *a*, *b*) is thread-like in appearance, uniformly white, except for the head sclerites, the legs, and a chitinized area on the caudal abdominal segment, which are pale chestnut brown. The mature larva is about 5 mm. in length and from 0.5 to 0.65 mm. in width, or approximately 10 times as long as wide.

The larvæ feed normally on the roots of cruciferous plants and remain concealed in the soil throughout their life.

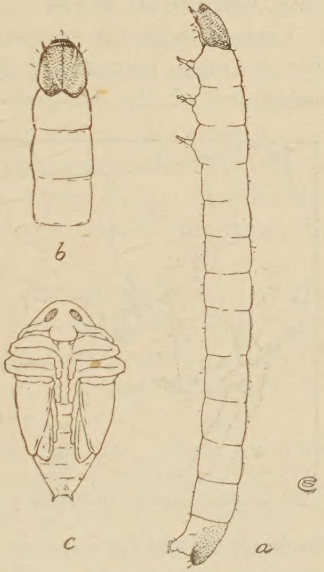

FIG. 2.—Western cabbage flea-beetle: *a*, Outline of larva, lateral view; *b*, head and thoracic segments of same, dorsal view; *c*, pupa. Enlarged.

PUPA.

On reaching maturity the larva selects a suitable place for transformation and then wriggles about until it has formed a compact, well-defined cell in the soil, in the vicinity of the roots on which it fed. After the cell is formed the larva shortens and in about two days changes to pupa.

The pupa (fig. 2, *c*) is approximately of the same size as the adult and is entirely white. The arrangement of the antennæ, legs, and wings is the same as that of the average halticine pupa.[3]

DISTRIBUTION.

The range of the western cabbage flea-beetle, accorded by Horn and others, is from the Dakotas to Mexico and central and southern California.

[3] Detailed descriptions of the immature stages are omitted from this paper because fresh material is not available and it is, moreover, desirable to compare all of these stages with those of related species and illustrate the same.

It is widely distributed in the Rocky Mountain region of Colorado and New Mexico, and is known to occur in more isolated localities in Arizona, Wyoming, Nebraska, Oklahoma, and Kansas. It is also abundant in some portions of Texas, ranging southward to Brownsville and undoubtedly into Mexico, although only doubtfully recorded from that country. The known distribution is shown in the map (fig. 3). This species is to be found quite frequently at very high elevations and is also evidently a permanent inhabitant of lower areas, as, for example, Brownsville, Tex. It is evidently a Sonoran form and common to both the Upper and Lower Sonoran Life Zones,[4] but in some States it has been observed in the Semitropical, Transition, and Boreal Zones.

Undoubtedly the species has a wider distribution than is indicated by the map, comprising an area considerably larger in extent than one-third of the United States. It probably occurs in southern Idaho, and without doubt is more widely distributed in the States of Nebraska, Wyoming, Montana, Utah, Arizona, and Texas than is at present known. While it does not approach the border lines of several other States known to be inhabited, nevertheless a lookout should be kept in the future for invasions in southwestern Louisiana, southeastern Idaho, and Nevada.

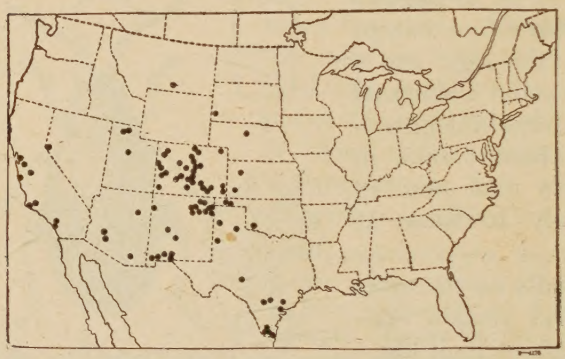

FIG. 3.—Map showing distribution of western cabbage flea-beetle.

REPORTS OF INJURY.

Our record of injury positively attributable to the western cabbage flea-beetle begins in 1889, the year when the species was described as new to science. That year, May 25, Prof. T. D. A. Cockerell sent specimens to the Department of Agriculture with the report that the insect did great damage to the leaves of turnip at Westcliffe, Colo. Injuries were reported at intervals in 1893, 1897, 1904, and 1906. In 1908 and 1909 there were several outbreaks over considerable territory, and a somewhat smaller outbreak occurred also over a large territory in 1913.

In 1893 Prof. R. Y. Croydon sent specimens from Laramie, Wyo., that were damaging turnips and radishes.

[4] The species came under the observation of the junior writer at Rocky Ford, Manzanola, Fowler, Las Animas, Loma, Holly, Pueblo, Colorado Springs, Fort Collins, and Greeley, Colo.; Garden City, Kans.; Maxwell and French, N. Mex.; Sanibel and Mercedes, Tex.; Phoenix, Ariz.; and Thermal, Calif.

In 1897 specimens were received, July 10, from Mr. D. A. Pierce, Kennedy, Nebr., with the statement that the species had destroyed between 10 and 20 acres of corn in 24 hours. They were said to destroy everything in gardens. They came in swarms of black clouds and covered the plants. Later in the month Mr. Benj. F. Henry, Hill City, S. Dak., complained of a "flea"—a name commonly applied by farmers to flea-beetles—that was troublesome on cabbage and other cruciferous crops in his vicinity. Only a single grower in his neighborhood had saved any cabbage, all others having given up the fight against this flea-beetle. In addition to cabbage this species was injurious to radish, horse-radish, and turnip, and was stated also to injure peas. On the last-mentioned plant it ate the lower leaves or lower part of the stalk. Out of 1,000 good cabbage plants our correspondent saved only a hundred. The beetles seemed to prefer the younger plants, but thrived also upon the older ones. A neighbor of our correspondent reported that he had not raised a turnip for seven years on account of this insect. It was prevalent in injurious abundance throughout the region of the Black Hills. The beetles were first noticed the last week of June, and seemed to disappear toward the end of July.

In 1904, during the first week of June, this species was observed by Prof. E. G. Titus, at Paonia, Fort Collins, and Longmont, Colo., and at Blackfoot, Idaho, June 22, attacking sugar beet. May 19, 25 acres of sugar beets were reported destroyed to date by this beetle at Grand Junction, Colo.

In 1906, Miss Hannah Carr, Mineral Hill, N. Mex., wrote January 11 of this insect destroying crops in that locality, particularly turnips, beans, and cabbage. From an acre of turnips only a few pounds of the vegetable were obtained. The same year complaints of injury to cabbage, radish, and nasturtium were received from Mr. Nathan Hall, Socorro, N. Mex.

The year 1908 witnessed severe outbreaks of this pest. April 24 Miss Margaret Botchleott, Grady, N. Mex., sent specimens with complaint of injury to garden plants. At Chico, N. Mex., it was injurious to cabbage. January 22, Mr. D. K. McMillan observed many beetles on turnip at Corpus Christi, Tex. The same year the species was received April 27, and later, from Mr. C. A. Pugh, Verne, Okla., where the beetle was reported to be injuring garden truck generally. June 4 Mrs. Frank Perron, Hurley, Tex., sent specimens with report that the beetles were entirely destroying radish and cabbage crops in the Coldun Tract in the panhandle of Texas. Mr. A. Olson, Blacktower, Roosevelt Co., N. Mex., October 25, writing of this species as the "garden flea" stated that it was generally found on radish, beet, lettuce, and in fact on almost all kinds of plants when they first come up. The insect perforates the small plants with holes and eats the substance until they die. The beetles were very

hard to catch and did great damage. The same year injuries were also reported to gardens in Verne, Okla., in April and May, and an invasion occurred at Brownsville and at Harlingen, Tex., on turnip and cabbage, in November. According to reports by Mr. McMillan, the beetles were to be found continuously through the month of November in south Texas.

In 1909 Mr. H. J. Kelley, Springton, Idaho, complained of this species, June 18. It was observed by Mr. M. M. High attacking potato at Lyford, Tex., March 2, and turnips and radish at Brownsville, Tex., March 26. July 25, of the same year, complaint by Mr. R. E. Chevick was made in regard to the same insect, on beans, cabbage, sugar beet, garden beet, and mangels. During July also, Mr. G. E. Thompson reported it at Akron, Colo., on kale and rape, and a heavy infestation at Fort Collins, stating that farmers complained of serious injury in their gardens, especially to cabbage, radish, and peas. November 7, H. M. Russell found the beetle at Compton, Calif., feeding on wild mustard.

In 1910 beetles were observed by Mr. High at Brownsville, Tex., in January, February, and March in large numbers on turnip, radish, and lettuce, doing great damage to young plants, the underside of the leaves being covered with excavations made by them. He wrote "in time this greatly devitalizes the growth of the plants and if the present number remains long enough, many of the leaves will wilt and die." March 2 the species was observed in numbers on young Irish potatoes at Lyford, Tex., by Mr. A. Steller.

During 1911, Mr. McMillan stated that in January and February this flea-beetle had been numerous at Brownsville, Tex., on wild water-cress (*Roripa sphaerocarpa*), wild pepper-grass (*Lepidium virginicum*), and on young turnip, mustard, and rutabaga. The beetles pass through partial hibernation, but their wild hosts were only slightly injured. July 2, this species was the subject of complaint at Goodwell, Okla., by Mr. Gus Shubert, who stated that in spite of different plantings the insect, locally known as the "earth flea," damaged radish, turnip, and cabbage. Serious infestation was reported the following day at Akron, Colo., to cabbage, lettuce, radish, and peas, and on July 25, to beans, cabbage, and sugar beets at Dulce, N. Mex.

June 10, 1912, injury was reported at Moses, N. Mex., to cabbage, radish, and turnip.

In 1913 this flea-beetle was observed in large numbers, January 27, at Brownsville, Tex., by Mr. High, attacking radish and turnip. The leaves were full of small holes made by the beetles. Injury was less noticeable on spinach and table beets. May 17, it was quite abundant on cabbage. Small excavations had been made on the underside of the leaves but were not yet entirely through the upper

covering. During the same year further injuries were reported to turnip, mustard, and radish at Amarillo, Tex.; to radish at Sheridan Lake, Colo., and to radish and turnip at Albert, Union Co., N. Mex. Of the last occurrence our correspondent wrote, "we can not raise these crops for the flea eats them as soon as they come through the soil." It was also injurious to cabbage, turnip, mustard, and radish at Tucumcari, N. Mex., and to radish at Thermal, Calif.

During 1914 Mr. F. B. Milliken reported this species attacking *Lepidium pubecarpum* at Garden City, Kans. He also observed larvæ from which the beetle was reared, May 17.

During 1915 this species was reported injurious to cabbage at Chico, N. Mex.; in 1916 to radish and cabbage at Fort Stanton, N. Mex.; and in 1917 to turnip, radish, and tomato at Golden, Colo.

During 1919 this species was apparently rare, having been reported in only four localities. At Brownsville, Tex., Mr. High found it attacking crucifers, and Mr. C. F. Stahl, Bureau of Entomology, collected specimens at Riverside, Calif., June 10 and July 14 on corn leaves. During July it made its appearance in injurious numbers at Lake Valley, N. Mex., where it was reported by Mr. John Avirette, attacking mustard, radish, and cabbage in the order named. He stated that without constant spraying with arsenicals these crops would all be ruined. August 26 of the same year Mr. A. E. Mallory, Bureau of Entomology, observed this species in moderate number on turnip.

July 16, 1920, Mr. D. J. Balagna, a grower and shipper of vegetables, Florence, Colo., wrote that this beetle was "destroying the entire valley," and unless something was done promptly, cabbage, cauliflower, and all related vegetables would be destroyed. Our correspondent had tried nicotine sulphate, coal oil and soap, arsenate of lead, salt water, lime, and Paris green, but found nothing that would kill it.

FOOD PLANTS.

The western cabbage flea-beetle, although normally an enemy of cruciferous plants, frequently does much injury to sugar beets and other vegetable crops. Turnip (*Brassica rapa*), mustard (*B.* spp.), and radish (*Raphanus* spp.) are decidedly the favorite food plants. The beetles also attack horse-radish (*Radicula armoracia*), rape (*Brassica napus*), cabbage (*Brassica oleracea*), cauliflower (*B. oleracea* var. *botrytis*), water cress (*Radicula nasturtium-aquaticum, Roripa nasturtium*), Chinese mustard or pe-tsai (*Brassica juncea*), nasturtium, bee-plant (*Cleome serrulata*), sweet alyssum (*Alyssum maritimum*), candytuft (*Iberis* spp.), wild peppergrass (*Lepidium pubecarpum, L. virginicum, et al.*), hedge mustard (*Sisymbrium* spp.), wild water cress (*Roripa sinuata* and *R. sphaerocarpa*), and tansy mustard (*Sophia pinnata*). All of these are normal food plants.

When the beetles occur in great abundance they injure also sugar beets and table beets (*Beta* spp.), mangel-wurzel (*B. vulgaris* var. *macrorhiza*), lettuce (*Lactuca sativa*), beans (*Phaseolus* spp.), peas (*Pisum sativum*), carrots (*Daucus carota*), tomato (*Lycopersicum esculentum*), potato (*Solanum tuberosum*), and corn (*Zea* spp.).

Injury is due to the beetles eating pitlike holes in the leaves of young plants, usually selecting the lower surface. Radish is so seriously attacked practically everywhere within the destructive range of this pest that it is almost impossible in such regions to grow this vegetable unless strenuous efforts are made to prevent the inroads of the flea-beetle. Turnip and mustard are about equally attractive to the beetles and unprotected beds are frequently destroyed. Important injury to cabbage is confined to young plants in seedbeds or to plants soon after they have been transplanted in the field. Horse-radish is readily attacked and the foliage is often so completely riddled that it has the appearance of a sieve when held up to the light. This plant, however, is very resistant and the roots attain a good growth in spite of severe attack to the leafage

The larvæ have been observed on radish, Cleome, and *Lepidium pubecarpum* only, but doubtless live on the roots of many other cruciferous and related capparidaceous plants. The injury done by the larvæ is negligible, so far as our observations go, in which respect this species differs from the related striped cabbage flea-beetle and horse-radish flea-beetle.[5]

SEASONAL HISTORY.

In its more northern range the beetle passes the winter months in hibernation under clods of earth, or under heaps of weeds, dead leaves, or other rubbish, whence it comes forth with the first warm days of spring. In the extreme South the beetles are active throughout the year but reproduction does not occur during the winter. In the Arkansas Valley the beetles issue from their winter quarters during the latter part of March or early April. At first the foliage of *Sophia pinnata* and horse-radish supply them with food. From these plants they go to early mustard and radish, and throughout the season or until severe freezes have occurred the beetles are to be found on various cruciferous vegetables and weeds. In south Texas beetles occur afield from February until December, being found, with the exception of two months, practically throughout the year.

There are apparently three generations annually in Otero County, Colo. Egg laying begins within a few days after the beetles leave their winter quarters—as early as April 14—and continues until early September.

[5] *Phyllotreta vittata* Fab. and *Ph. armoraciae* Koch, respectively.

LIFE HISTORY AND HABITS.

OVIPOSITION.

Opportunity was afforded for observing the female of this flea-beetle in the act of laying her eggs, beginning June 18, 1915, at Rocky Ford, Colo. In a period of 12 minutes 17 eggs were deposited. When fully extruded, the ovipositor is from one-third to one-half the length of the abdomen. The total time taken in laying an egg varied from 2 to 5 seconds, 3 seconds being the average. During the laying there is a contracting movement of the abdomen, the ovipositor is extruded—not always to its full length—and an egg is forced through the opening. If, when the egg is forced out, it does not strike a surface and adhere to it the female twists the ovipositor about until the egg comes into contact with a surface to which it adheres. After an egg was laid the female generally ran about for a few seconds, then stopped and remained quiet for a few more seconds before laying another egg. Three different times the succeeding egg was laid at the same place within 3 or 4 seconds of the preceding one. As far as could be determined the eggs were not deposited in any particular order or arrangement, but were distributed quite promiscuously over the surface of the glass in the rearing cage. After having laid the last egg, the female ran down on the stem of a turnip leaf, which was in the cage, and commenced to eat. No further egg laying was observed, but as four other eggs were found it is presumed that they were laid before these observations began, which would give a total of about 21 eggs laid at this time.

Subsequently eggs were found in various other locations, one mass of 20 being laid on the soil, another of similar number on the lower surface of a turnip leaf, while others were scattered in small masses about the crowns of the plants.

The number of eggs that might be deposited by a single beetle was very difficult to ascertain and although attempts were made only two records of egg laying were obtained.

September 6, 1915, three beetles, two females and a male, developed in the cages at Rocky Ford, Colo. They lived through the winter under bits of earth in a rearing jar, and March 29, 1916, the male mated with one of the females. This pair was isolated in another cage and the record of the eggs deposited is given in Table I.

TABLE I.—*Egg-laying record of a single female of Phyllotreta pusilla.*

Date.	Number of eggs deposited.	Date.	Number of eggs deposited.
1916.		1916.	
April 3	21	May 21	19
12	27	25	32
21	23	29	27
29	23	June 6	21
May 6	16	13	20
9	15	Total	244

The female died June 20, and the male July 31.

The second female, which developed September 6, 1915, deposited 193 eggs beginning March 26 and ending July 26, 1916. She died July 30.

Females collected in the field and confined deposited from 27 to 163 eggs each, indicating that many of their eggs had been deposited before they were confined.

HABITS AND BEHAVIOR.

It was noticed in the occurrence of this insect in Otero County, Colo., that the beetles could best be collected during the middle of the day, the time when they were most active and were out on the plants in larger numbers. Earlier or later in the day they were usually found lower down on the plants around the crown or in cracks in the ground.

FIG. 4.—Device for collecting flea-beetles for study.

In order to collect them in numbers, a collecting bottle fixed somewhat as follows was used and found satisfactory: The bottoms of two small vials are broken out and then put end to end through the cork of the larger bottle (fig. 4). Upon inserting the neck of the outer vial over a beetle, it will invariably jump up into the vial. The neck is useful in that the beetle has a support to fall on if it does not secure a footing on the side of the vial. Hundreds of beetles can be collected in a bottle of this kind with small possibilities of any escaping. This form of bottle has been successfully used for the capture of other species of flea-beetles.

Adults mated from the middle of June to the middle of July, and were sufficiently abundant to do noticeable damage to small plants. Small radish plants were very much injured by the beetles eating into the stalk at the top or just below the surface of the ground, causing the plants to wilt and die.

In rearing experiments considerable care is required to see that the soil, or whatever the insects are in, does not become too wet or too dry. If the eggs are allowed to become too wet, they do not hatch; if not moist enough, they shrivel and dry up. In general, eggs require soil that is moderately moist.

The greatest difficulty in life-history studies was encountered in the larval stage. The larvæ were easily killed by excessive moisture, especially when accompanied by heat. Probably several thousand larvæ hatched but only a few lived to be adults. The most susceptible period is just after the larvæ have hatched. The laboratory temperature varied from 65° to 80° F. or above, with the maximum temperature for the larvæ about 70° F. This approxi-

mated more nearly the soil temperature in the field. Much below this the larvæ did not develop well and above 80° there was a considerable increase noticeable in the death rate. If too much moisture accumulates in rearing jars or "cages", the air becomes saturated during the day and at night cools off and condenses. This is detrimental to the larvæ, as they often become submerged in drops of water.

The young larvæ feed on the hair roots of their food plants and the older ones feed also on the main stalk and branches.

It was necessary to supply fresh roots every two or three days as decay is apt to set in. Parts of the crown of small turnips were supplied to the larvæ as food and they fed on this readily but did not seem to do as well as on fresh radish roots.

Upon reaching maturity the larvæ cease feeding and crawl restlessly around for a day or so before entering the soil. They make a distinct pupal cell with the inside compact and tightly cemented. Larvæ were observed in these cells, in a number of cases, for several days before they began to shorten. The contracted prepupal period ordinarily lasts 4 or 5 days.

Several times soil was secured in the field and brought to the laboratory and examined for larvæ or pupæ of this flea-beetle. In no instance was any larva or pupa observed. A number of examinations for larvæ and pupæ were made by digging around the roots of growing turnips and radishes, but neither was ever found in the field.

Since the eggs and larvæ in the laboratory seemed to be so susceptible to excessive moisture, the opinion was reached that it might be possible to control the species in the egg, larval, and pupal stages in the field by the practice of irrigation. Whenever the plants are irrigated, the soil around the roots is quite thoroughly soaked and it seems likely that the eggs, larvæ, and pupæ may not be able to withstand this.

LIFE CYCLE.

In working out the life history of the western cabbage flea-beetle adults were captured in the field and confined in cages consisting of battery jars and glass-covered boxes. The lid of a small tin salve box, filled with moistened earth, was placed in each cage, and in this earth the beetles deposited their eggs. The lids containing the earth were removed daily or at intervals of two or three days and placed in larger salve boxes. Food was supplied the larvæ by placing sprouted radish seed on the surface of the earth in the boxes. As the larvæ neared maturity most of the earth was removed from the lids in order to enable a close observation of the pupæ.

Owing to the extreme delicacy of the larvæ, it was impossible to rear large numbers at any one time. The small numbers of beetles which developed showed little disposition to breed and it was not possible to determine the number of generations occurring annually from any given "stock," or lot of specimens. The rearing records obtained, however, indicate the probability of three generations occurring annually in Otero County, Colo.

In Tables II, III, and IV records of the observed generations of the western cabbage flea-beetle in 1916 are given:

TABLE II.—*First generation of western cabbage flea-beetle.*

Item.	First generation.
	1916.
Adults captured and confined	April 10
First eggs deposited	14
First eggs hatched	24
First larvæ pupated	May 26
First adults developed	June 8
	Days.
Egg stage	10
Larval stage	26
Pupal stage	11
Total duration	50

TABLE III.—*Second generation of the western cabbage flea-beetle.*

Item.	Second generation.
	1916.
Beetles confined	June 24
First eggs deposited	26
First eggs hatched	July 7
First larvæ pupated	19
First adults developed	25
	Days.
Egg stage	5
Larval stage	18
Pupal stage	6
Total duration	29

TABLE IV.—*Third generation of the western cabbage flea-beetle.*

Item.	Third generation.
	1916.
Beetles confined	Aug. 8
First eggs deposited	12
First eggs hatched	19
First larvæ pupated	Sept. 10
First adults developed	20
	Days.
Egg stage	7
Larval stage	22
Pupal stage	10
Total duration	39

HISTORY AND LITERATURE.

An account of this species, mentioned under the name of the Colorado cabbage flea-beetle (*Phyllotreta albionica* Lec.), was published by Riley in his 1884 report (*1, p. 302*),[1] in which he stated that it was injurious to cabbage and other cruciferous plants in June and July throughout the Rocky Mountain region of Colorado, having been found in great numbers at the very highest elevations.

In 1885 Prof. T. D. A. Cockerell (*2*) mentioned this species under the same name, quoting from Riley's report. In a footnote, written by hand in a copy of his paper, appears "Dr. Horn says this is *pusilla* Horn and not the true *albionica* Lec." The same year Dr. Horn (*3, p. 302*) published the original description of the species.

In 1893 an editorial account of this species was given by Dr. L. O. Howard (*4*), citing injury at Kennedy, Nebr., and Hill City, S. Dak., previously considered in this bulletin under the heading "Reports of injury," p. 4.

In 1900 Messrs. Forbes and Hart (*5, p. 471*) published an account of this species under the title "The western cabbage flea-beetle, *Phyllotreta albionica* Lec.," stating that it was reported by Bruner as injuring sugar beets in Nebraska, and by Gillette as infesting cauliflower and other cruciferous plants and the bee-plant (*Cleome integrifolia*).

In 1903 the writer published a brief account of this species under its proper name, stating that it was observed doing considerable damage to sugar beet in portions of Colorado during 1901, preferring the younger plants (*6, p. 18*).[2]

In 1905 this species was recorded (*7, p. 572*) in brief as having been very destructive to radish, turnip, cabbage, and some other truck crops in Oklahoma, Texas, and New Mexico, in 1905.

NATURAL ENEMIES.

The western cabbage flea-beetle is singularly free from natural enemies. The three species, other than birds, which have come under observation are all internal parasites.

A BRACONID PARASITE.

Perilitus epitricis Viereck, a braconid ichneumon-fly parasite of the adult beetle, was found during practically all the three summer months. It was most abundant from the latter part of June to the latter part of July. Two adults emerged September 13, and one larva was found the same date. The larva probably emerges through the abdomen and under the elytra, although this point was not

[1] Figures (thus) in parentheses refer to "Literature cited," p. 21.

[2] Remarks made by Prof. S. A. Forbes (1, p. 86) "that the beetle in this region is the cause of considerable injury to turnip and cabbage in the Yellowstone Valley, Mont." may refer to the related *Ph. pusilla* Horn, or to *Ph. albionica* Lec., although *Ph. pusilla* is known to occur in that part of the state.

proved. The larva spins a light gray cocoon in which it transforms to pupa, and the adult parasite emerges through a small hole which it eats out of the end of the cocoon. The greatest percentage of parasitized beetles observed at any one time was 16.

Just what influence this parasite has in holding the beetles in check has not been determined. It is sometimes an important enemy of the related striped cabbage flea-beetle (*Phyllotreta vittata* Fab.)

A NEMATODE PARASITE.

Nematodes infest the adult beetles. As generally observed these nematodes were young and small, about 1/40 of an inch in length. From 200 to 500 were counted in a single beetle. In several instances adult female nematodes were observed which had the body sack filled with newly developed nematode young that had not yet escaped.

As nearly as could be determined the nematodes were not confined to the digestive tract but appeared to be in the body cavity. In a number of cases eggs laid by the beetles were found to be infested externally with the nematodes. The eggs had an unhealthy appearance and in no instance were infested eggs observed to hatch. Just what effect the nematodes have on the beetles would be an interesting problem to work out.

A GREGARINE PARASITE (GREGARINA).

Gregarine worms [9] occur in the intestines of the adult beetles, infestation averaging as high as 40 to 50 per cent, but it could not be determined whether these had any detrimental effect upon the host. They occur in almost all forms of insects and as far as known have no serious effect on them.

BIRD ENEMIES.

Mr. W. L. McAtee of the Biological Survey reports having found the western cabbage flea-beetle in the stomachs of three species of birds, and other beetles of the same genus in the stomachs of 12 kinds of birds. The land birds include among enemies of these beetles the common and Texas nighthawks (*Chordeiles virginianus* and *C. acutipennis texensis*), white-throated swift (*Aeronautes melanoleucus*), horned lark (*Otocoris alpestris*), starling (*Sturnus vulgaris*), song sparrow (*Melospiza melodia*), chipping sparrow (*Spizella passerina*), tree swallow (*Iridoprocne bicolor*), and marsh wren (*Telmatodytes palustris*).

CONTROL MEASURES.

EXPERIMENTS WITH INSECTICIDES AND DETERRENTS.

Ten experiments with arsenicals and one with nicotine sulphate were made in Otero County, Colo., by the junior author, and may be summarized as follows:

[9] Identified by the junior author.

Experiment No. 1.—August 19, 1911.

Nicotine sulphate, paste	ounces..	3
Fish-oil soap	do....	8
Water	gallons..	10

It was noted that when the beetles were thoroughly wet with this spray they appeared to be soon killed. Later experiments, however, demonstrated that the beetles afterward came to life. Nevertheless, the single application showed considerable value, and if additional applications had been made to the same planting, the efficiency of this deterrent could have been demonstrated. Naturally no harm was done to the plants.

Experiment No. 2.—June 3, 1911.

Arsenate of lead was used with an equal amount of soap at the rate of about 6 pounds to 50 gallons of water, on radish, cabbage, and mustard, but as only one application was made the plants became reinfested.

Experiment No. 3.—June 22, 1911.

Arsenate of lead, paste	pounds..	6
Soap, common laundry	do....	6
Water	gallons..	50

In this experiment young cabbage was sprayed on both the upper and lower surfaces and the plants were heavily coated, almost whitewashed, the spray adhering well. This had the effect of deterring most of the beetles and although no dead ones could be found it was evident that the spray acted as a powerful repellent.

Experiment No. 4.—July 22, 1911.

Arsenate of lead, paste	pound..	1
Whale-oil soap	do....	1
Water	gallons..	10

This was applied to radish and cabbage, the leaves of the latter being badly pitted. Every portion of the plants was wet on both the upper and lower surfaces. As in the previous experiments no dead beetles could be found and, although rainfall washed away much of the arsenate, in four days the plants had improved wonderfully and made excellent growth. As the rain left the plants practically unprotected a second spraying was made of the same mixture two days later. Nine days afterwards the cabbage was in excellent condition and practically free from insect pests, only an occasional beetle being found.

Experiment No. 5.—September 5, 1911.

Nicotine sulphate, paste	ounces..	4
Whale-oil soap	do....	8
Water	gallons..	10

After the application of this spray it was noted that the beetles which came in contact with the treated leaves jumped wildly and and after a brief struggle apparently died, but revived within half an hour. The plants showed no injury from the spraying.

Experiment No. 6.—April 29, 1912.

Arsenate of lead, paste	pound	1
Whale-oil soap	do	1
Nicotine sulphate	ounces	5
Water	gallons	10

This was applied to young mustard plants which were so small that only the upper side was treated. In this case the beetles were apparently dead but after being confined in a cage revived within an hour. The following day the plants showed an even coating of arsenate on the upper surface and were almost entirely free from the beetles. Some of the worse pitted leaves had died, became very dry, and crumbled when touched, but this was due to the attack of the beetles and not to the insecticides. This plat was examined at intervals, and a week later the plants were growing excellently. As the beetles began increasing in numbers an additional spraying was necessary.

Experiment No. 7.—April 29, 1912.

Arsenate of lead, paste	pound	1
Whale-oil soap	do	1
Water	gallons	10

As in the previous experiment, the upper surface only was sprayed, radish and mustard being the plants treated. In this instance the infestation was so severe that many of the plants were so nearly destroyed that they failed to recover, partly because of hot, dry, and windy weather. It was only where the leaves were almost entirely consumed by the beetles that the plants died. The coating of arsenate was excellent and four days later the plants were growing well and were almost free from flea-beetles.

Experiment No. 8.—May 9, 1912.

The same formula as No. 7, applied to the same plants. Rain intervened for several days but nine days later the plants were described as growing beautifully and only moderately infested by flea-beetles, being beyond danger of injury. Although no dead beetles were found, the experiment was a success and the radishes were being sold at the time.

Experiment No. 9.—April 29, 1912.

A badly infested plat of mustard was dusted with dry Paris green inclosed in a cheesecloth sack, but there was a moderate wind and a considerable portion of the poison was blown away. The next day, however, although the plants were free from beetles they were nearly dead. Those which remained alive and were growing were practically free from flea-beetle attack.

Experiment No. 10.—May 2, 1912.

Arsenate of lead, paste	pound	1
Whale-oil soap	do	1
Water	gallons	10

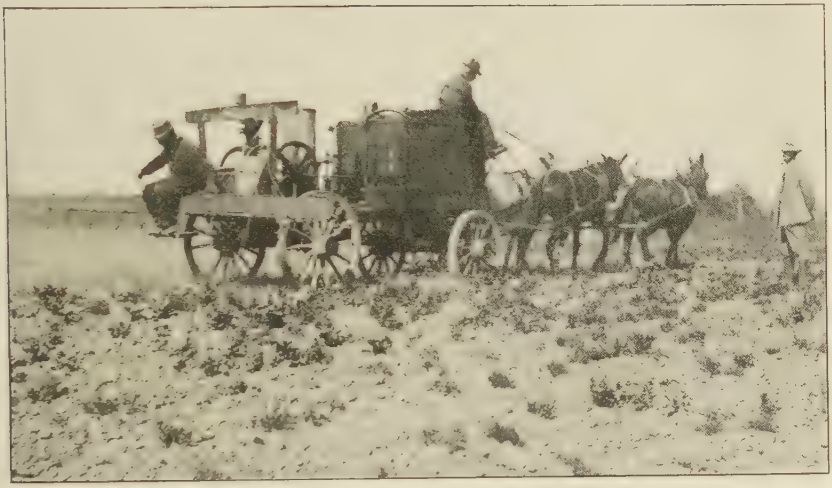

FIG. 1.—SPRAYING BEET FIELDS IN CALIFORNIA.

FIG. 2.—DUSTING CABBAGE WITH LEAD ARSENATE BY MEANS OF A TRACTION DUSTER.

THE WESTERN CABBAGE FLEA-BEETLE.

In this experiment radishes were sprayed and only the upper side was treated. A good quantity of the poison remained, no injury resulting from the spray, but no dead beetles could be found. Nine days later a rain fell, leaving many leaves unprotected, the beetles becoming abundant.

Experiment No. 11.—April 29, 1912.

A badly infested planting of mustard was dusted with undiluted arsenite of zinc. As in the foregoing experiment a moderate wind was blowing at the time and carried much of the poison away. The result, however, was practically the same, some of the poison remaining on the leaves, and although no dead beetles were found the plants were comparatively free from flea-beetle attack a week later.

It should be remarked that the plants at this time needed water but the irrigating ditch was dry.

RECOMMENDATIONS.

It appears to be practically impossible to kill an appreciable number of the western cabbage flea-beetles by spraying with arsenicals. Repeated experiments have shown that whatever application may be made does not kill the insects but drives them away. In other words, this insect can not be controlled by poisons, but by repellents and deterrents. The beetles are dainty in their feeding habits, carefully avoid foliage which has been sprayed, and attack either unsprayed portions or fly to other plants. Repellents such as tobacco dust are the most efficient of those which have been tested, and of the arsenicals, heavy applications of arsenate of lead have given the most satisfactory results.

LEAD ARSENATE.

In large plantings, and especially where cabbage is infested, spraying heavily with arsenate of lead is advised (Pl. I, fig. 1). The following formula has given excellent results:

Arsenate of lead, paste	pound	1
Fish-oil soap (as a sticker)	do	1
Water	gallons	10

This is at the rate of 5 pounds of lead arsenate to 50 gallons of water, or a trifle stronger than the standard formula of 4 to 50. One-half this weight of powdered lead arsenate, or 2 pounds in 50 gallons of water, is equally effective, with a corresponding quantity of soap to act as an adhesive or "sticker." It should be applied with a sprayer fitted with elbow extension, and a special effort should be made to coat thoroughly the under surface of the leaves. Two or three applications at 5 to 8 day intervals are sufficient even in case of severe infestation, provided the first application is made promptly on the first appearance of the insects.

BORDEAUX MIXTURE.

It has been known for many years that Bordeaux mixture is an almost perfect deterrent against flea-beetles. There is something extremely distasteful in it to this class of pests but unfortunately it has not been tested thoroughly either alone or in combination with arsenicals. It is recommended that tests be made both alone and in combination with arsenate of lead, arsenite of zinc, and calcium arsenate against this species. The standard Bordeaux formula 4–4–50 should be employed.

NICOTINE SULPHATE.

Experiments were made with nicotine sulphate at the rate of 3 ounces with whale-oil soap, 8 ounces, in 8 gallons of water, with the result that the beetles were stupefied although not killed. In these instances there is abundant proof that the flea-beetles were strongly repelled but further experiment is desirable to determine how often this preparation should be used, that is, at what intervals. Naturally since tobacco dust has been found successful, nicotine sulphate should be nearly as useful if not equally so.

INEFFECTIVE DETERRENTS.

In some regions where the western cabbage flea-beetle is destructive, growers dust the infested plants with air-slaked lime, ashes, insect powders, soot, or Paris green, but experiments made in Colorado have demonstrated that beneficial results from these substances, which also act as repellents, are of short duration in that State. The dry, high winds which prevail there render it difficult to apply an even coating of any form of dust or powder or to make such material adhere to the lower surface of the leaves where it is usually most needed.

A better coating, however, may be applied to the rough-leaved foliage of turnip, radish, and mustard than to the smooth-leaved cabbage, and some growers claim that the former class of crops may be efficiently protected by dusting with lime.

TOBACCO DUST.

A liberal application of finely ground tobacco dusted on the infested plants at 3 or 4 day intervals can be depended upon to protect radish, turnip, mustard, and similar vegetables from the beetles and for use on small areas is one of the most satisfactory control measures that can be recommended.

The accompanying illustration (Pl. I, fig. 2) shows a method of dusting with an arsenical or deterrent by means of a traction sprayer.

MAINTENANCE OF THRIFTY GROWTH.

In regions where the western cabbage flea-beetle is a dangerous pest the farmer is advised to keep the plants in vigorous condition

by frequent cultivation and heavy manuring in order to stimulate the growth of the plant and enable it to recuperate from insect attack. The irrigation system should be so installed that it may be kept constantly in working order, that the plants may not suffer at any time for lack of moisture. It should be unnecessary to add that the crops be kept free from other insects and from disease.

IRRIGATION.

Irrigation has been suggested as a remedy for the hop flea-beetle in its occurrence on sugar beets and should be of value where irrigation is practiced on other crops. Its effectiveness could be increased by brushing the plants, causing the beetles to jump into the water and be carried away or drowned.

MECHANICAL TRAPS.

The use of sticky shields and tarred boards, which have proved effective in the control of the hop flea-beetle in hop yards, might be used against this pest when it occurs in its greatest numbers. The conditions, naturally, are different, but there might be some cases where either would prove effective.

In 1914 Prof. H. M. Lefroy (*9*) made use of what he calls the Wisley turnip-fly trap against two allied species of flea-beetles [10] in their occurrence on turnip with what he describes as amazing results, due apparently solely to the growth the seedlings make when their leaf surface is entirely unharmed. This trap is made of two boards set at a slope on a pair of runners like those of a sledge with a space between. The trap is drawn along the rows so that the plants pass through the space in the middle. In order to disturb the beetles a loop hangs from a crossbar and brushes the plants. The boards are smeared with a sticky substance, which captures the beetles as they fly up. The illustrations furnished of the trap show that it can be easily made and should prove quite successful where radish, turnip, and similar crops are planted in rows, but, of course, would not be of service where the seed is sown broadcast.

TRAP CROPS.

The fondness of this, as well as other cabbage flea-beetles, for radish, mustard, and turnip suggests the employment of these as early trap crops to attract the beetles from the later-appearing main crops of cabbage, sugar beet, and others. The beetles may be swept up from these trap crops by means of a bag sweep net of the type used by entomologists to collect beetles and similar insects. This should afford protection for the main crop.

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[10] *Phyllotreta consobrina* Curt., and *Ph. undulata* Kutsch.